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AN
ESSAY
ON
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ANIMALS.

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——————— *Sic sine vitâ*
Vivere, quàm suave est, sic sine morte mori.

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PREFACE.

In the conclusion of my Inaugural Dissertation, published at Edinburgh in 1803, I promised to investigate more fully the torpidity which certain animals experience during winter. I now perform that task imperfectly, rather than leave the subject any longer unnoticed. The following Essay has been written in the intervals of professional employment, and I now make it public, with a hope to convey some useful information.

That

That it does not contain a complete view of all the bearings of the question concerning torpidity, I am well aware, because some parts of that subject are of the greatest possible complexity. I have collected the principal facts relating to this curious inquiry which I could find in various authors. To the posthumous work of Spallanzani, published by Senebier under the title "Rapports de l'Air avec les Etres organisés, 3 tom. à Genève, 1807," I am indebted for many illustrations of the reasonings which I have brought forward; and I have availed myself of the experiments and observations of others, wherever they appeared more conclusive than any

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of my own. I did not meet with a little work on the Brumal Retreat of Swallows, until this Essay was just finished. My regret in not seeing it sooner has been lessened by finding some of my opinions confirmed by the observations of the author, who signs himself *Philochelidon*.

In discussing the theory of respiration and the source of animal temperature, I have followed the doctrine taught by Mr. Allen in his lectures on the Animal Œconomy formerly delivered at Edinburgh. The effects of sudden changes of temperature often demand a physician's attention: the influence of heat and cold must therefore

therefore be a proper subject for his study and contemplation; since it leads to speculations which are intimately connected with physiology and the practice of medicine.

Norwich,
May 1*st*, 1809.

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TORPIDITY OF ANIMALS.

INTRODUCTION.

THE more we reflect on the different forms of existence, the more do we perceive the wonderful adaptation of the different orders of animals to the circumstances in which they are placed; and whilst we discover a wisdom and contrivance beyond the sagacity of the human mind, we are enabled to derive some knowledge of the œconomy and

functions of the human body.—Thus, in the ordinary conception of physiologists in every age, a power of generating heat, and an uniformity of temperature, have been considered the grand characteristics of animal life. The temperature of animals has been thought to remain always the same, notwithstanding the variations of the medium to which they were exposed; and although this is nearly true as far as man and some of the nobler animals are concerned, yet it is erroneous when applied to animals in general. And the error to a great extent is common to some of the best writers on physiology. Many speak of the power of resisting cold, of the power of generating heat, and even of acting upon substances in opposition to the laws which regulate unorganized bodies, and they apply to these apparent exceptions to the ordinary

course

course of nature, the terms, *vital power*, *living principle*, *vitality*, *life*.

Instead of this uniformity of temperature, however, instead of a constant and regular action depending on the power by which living bodies are preserved from decomposition, we find such temperature subject to considerable variation; and so great is the mutual agreement between the different parts of an organic body, that any modification of one principal function has a corresponding influence on all the rest. Hence the chemical philosophy opposes a different explanation to the common opinion; and though the explanation which it affords is at present confessedly imperfect, yet it seems to be well founded as far as it goes, inasmuch as it shows the necessity of a continual circulation of particles in living bodies, and points out the limits

within which the vital powers are restrained.

Man, wherever he is found, has acquired and maintained a superiority in his physical as well as his moral faculties over the rest of the creation. He is enabled, by a more perfect organization, to preserve nearly the same temperature under great extremes of heat and cold. Most of the inferior animals are confined within certain limits; but the human constitution has sufficient vigour to withstand the severity of the most rigorous climates, and sufficient flexibility to adapt itself to the most diversified circumstances. Hence it happens that, whilst the lower animals appear only in certain conditions, where the temperature and food are suited to their wants, man is seen under the greatest variety of situations.

Connected

Connected with this remarkable difference between man and the brutes, there is an inquiry of the greatest curiosity. If animals be ever placed in such circumstances as not to be able to procure food, and rendered incapable, by the action of cold, of exercising the two important faculties of sensation and voluntary motion, is there any provision of Nature which will ensure their preservation? Experience tells us there is. We know that a very large portion of organic beings become torpid at the approach of winter; and when we consider the immense tribes of insects, worms, and oviparous quadrupeds, the number of hybernating animals is greater than that of those which remain unaffected by cold.

Nothing is more striking amidst the variety of instinctive habits of animals than this torpor or lethargy, which so many

many of them experience at certain seasons of the year, or when placed in peculiar circumstances. A continuance of life under the appearance of death, a loss of sensibility and of voluntary motion, a suspension of those functions most essential to the preservation of the animal œconomy,—these are the phænomena which accompany the torpid state, and they constitute one of the most singular problems in the whole range of natural philosophy.

It has been a favourite object of my inquiries to investigate the series of changes which the different species of animals undergo during their hybernation, and to ascertain the general causes which induce them to submit to that suspension of existence. I was led some years ago to pursue this inquiry, because it appeared to me capable of throwing light

light upon an interesting part of natural history, as well as of illustrating some important points in physiology and medicine.

The influence of different degrees of temperature on the human body richly deserves attention; and comparative anatomy, aided by chemical and physiological observations, seems to be the path which is to lead to future discoveries. By investigating the functions of animals whose organization is the most simple, we may be assisted in arriving at some knowledge of the vital processes in animals of a more complicated structure, and our acquaintance with the whole is likely to be increased by studying the mutual relations of different parts.

I propose first to describe the phænomena common to all those animals which

which become torpid during winter, and then to draw some general conclusions, and to make some general remarks such as the facts stated authorize me to infer.

SECTION

SECTION I.

PHÆNOMENA OF TORPIDITY.

DURING their state of hybernation the temperature of the animals is considerably diminished, the circulation of the blood becomes slower and is sometimes almost entirely stopped, the respiration is rendered less frequent, and, when the torpor is complete, wholly suspended, the digestion ceases, and the action of the muscular and nervous powers is for a time suppressed.

Some animals of every class, except birds and fishes, afford examples of this suspended animation in the winter: the different

different species, however, are subject to different degrees of torpor; for some retain an inferior degree of sense and voluntary motion, whilst others lose these powers entirely. At the approach of cold weather, when the thermometer begins to sink below 50°, these animals retire to their holes in the earth, or in trees, or bury themselves in nests made of hay and dried leaves under ground, where they fall into a kind of sleep, and continue totally inactive until the warmth of the sun or the calls of appetite rouse them to the vigorous exertion of another mode of life.

Quadrupeds of this tribe, and indeed most of the hybernating animals, have the habit of rolling up their bodies into the shape of a ball during their ordinary sleep, and they assume the same form in their torpid state, so as to expose the least

least surface to the cold. One of these animals, the jumping mouse of Canada (*Dipus canadensis*), has been discovered completely enveloped in a ball of clay nearly an inch in thickness, perfectly smooth within, and it was found above twenty inches below the surface of the earth*.—The most familiar instances of torpidity are furnished by the marmot (*Mus. Marmota*), the dormouse (*Mus avellanarius*), the bat (*Vespertilio*), the hedgehog (*Erinaceus europæus*), and by flies, insects, worms, and oviparous quadrupeds, including under that title, frogs, toads, and lizards; and to these the snakes may be added.

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* Transactions of the Linnæan Society, vol. iv. p. 155.

I. *The temperature of hybernating animals is diminished.*

Experiments abundantly prove the truth of this first position. Some facts relating to this subject are to be found in the writings of Mr. John Hunter and other authors, and I have had opportunities of satisfying myself as to their general accuracy by actual experiments. The temperature sinks as the cold of the atmosphere increases, but remains somewhat higher than the medium in which the torpid animals are placed. In those called warm-blooded animals, the temperature varies from 102° to 45°, and even lower; and in amphibious and cold-blooded animals, the thermometrical heat falls to two-thirds of a degree above the surrounding

surrounding medium, and sometimes even to the same standard.

Mr. Hunter observed that the temperature of a hedgehog at the diaphragm was 97° in summer, when the thermometer in the shade stood at 78° *: when the surrounding medium was 44° the animal became torpid, and the temperature was reduced to 48½°:—when the atmosphere was 26°, the temperature is reported to have been reduced so low as 30°.

Pallas observed that the thermometer rose to 39¼° when placed in the belly of a torpid hedgehog; and Spallanzani never found the temperature of the surface of their bodies lower than 36°, nor did they become so completely torpid in the course of his experiments as to be insensible to stimuli or to the calls of

* Observations on the Animal Œconomy, p. 112.

hunger.

hunger. The average temperature of hedgehogs in summer is 96°, and I am disposed to think it is never reduced in winter much below 50°.

The internal temperature of the dormouse in its active and healthy state is 101°;—when rolled up and torpid in winter, the thermometer indicates 43°, 39°, and even 35° on the external parts of its body, and when introduced into the stomach indicates 67°, and 73°.—In an animal of the same tribe (the order of *Glires*), in Russia, Pallas found the temperature 103° during summer, and 84 in its torpid state. Marmots have a temperature 101°, 102°, which gradually sinks as they become torpid, till it comes down to 43°, and even lower.

Bats have a temperature nearly of the same standard in summer as that of marmots; they are soon affected by the changes

changes of the atmosphere, and they cease to respire in a medium whose temperature is 43°.—In the month of July, the thermometer standing at 80°, the internal temperature of a bat was 101°, which is just the degree of heat in a group of them collected together in summer, and may therefore be considered the natural standard.

Spallanzani sometimes found bats cold to the touch, breathing slow, with their temperature reduced, although the heat of the atmosphere was 80°; but probably this was owing to indisposition from confinement, or for want of proper food.—After being exposed an hour to temperature 43°, Spallanzani observed that the bulb of the thermometer placed in the chest of a bat indicated 47°, four degrees above the surrounding medium;—exposed to a temperature below the freezing point, the

the temperature of the animals becamo the same as that of the medium; yet it always remains internally higher than the low temperature produced artificially, though the skin indicates the same.

The wood-mouse (*Mus sylvaticus*) becomes torpid in the month of November in Italy; it appears to be sooner affected by cold than the dormouse or marmot. Spallanzani found one torpid when the thermometer in its cage stood at 43°,—the temperature of the belly externally was 45°, but its internal temperature is not much diminished even by a degree of cold sufficient to render it very torpid.

Frogs and other amphibious animals are destroyed by exposure for a long time to a temperature reduced within two or three degrees of the freezing point: they are therefore enabled to withstand our winters, which are always colder than that,

by

by making holes in the mud of ditches, or by burrowing into a moist and penetrable soil, and they sink deeper and deeper into these retreats in proportion as the cold increases. The temperature which surrounds them is about 41°, and their bodies indicate the same; they remain in a languid and inactive state, yet they do not become so completely torpid as the class *Mammalia*. This state may be induced by artificial cold; but if frogs be completely frozen, their life is irrecoverably extinguished, and in very hard winters they are sometimes destroyed in their natural hiding-places.

II. *The circulation of the blood becomes slower.*

All the observations which I have been able to make, and all those which I can find recorded by others, correspond

spond respecting this point, viz. the influence of cold in diminishing the action of the heart and arteries. It is proved most unequivocally by the effects of the effusion of cold water in febrile disorders, and still more by what occurs in hybernating animals.

The hamster (*Mus cricetus*) has only fifteen pulsations in a minute when it is torpid; yet in its active state, when irritated, its heart beats one hundred and fifty strokes within the same period of time. The common frequency of the heart's action in bats during summer is about a hundred pulsations in a minute; but when they are growing torpid, only sixty; and as the torpor increases, the action of the heart is so feeble that only fourteen beats have been distinctly counted, and those at unequal intervals. Dormice, when awake and jumping about,

breathe

breathe so rapidly that it is almost impossible to count their pulse; but as soon as they begin to grow torpid, eighty-eight pulsations may be counted in a minute, thirty-one when they are half-torpid, and only twenty, nineteen, and even sixteen, when their torpor is not so great as to render the action of the heart imperceptible. Spallanzani relates that he counted ten, eleven, and sometimes twelve pulsations in a snake at temperature 48°, whose pulse is generally thirty in warm weather.

In some experiments which I made at Edinburgh in the spring of the year 1803, I observed that the number of pulsations in toads and frogs was thirty in a minute, whilst they were left to themselves in the atmosphere of which the temperature was 53°; when placed in a

medium cooled to 40°, the number of pulsations was reduced to twelve within the same period of time; and when exposed to a freezing mixture at 26°, the action of the heart ceased altogether.

The action of the heart, however, in the higher species of animals, is not totally suspended, nor is the circulation entirely stopped, although the motion is too feeble and obscure, sometimes, to be perceived. This is proved by the blood remaining fluid: and the following curious fact, which I state on the authority of Spallanzani, shows that the blood retains its fluidity, and consequently its motion:—if the blood of marmots be subjected out of the body to a temperature even higher than that to which it is exposed in the lungs of the animals, it is instantly frozen; but it is never congealed

in

in their dormant state, even after exposure to cold several degrees below zero of Fahrenheit's scale*.

III. *The respiration is less frequent, and sometimes entirely suspended.*

I could never discover the least motion in the flanks of bats in a torpid state, except when they were roused by the warmth of the hand, or by any other cause; and on leaving them alone, their respiration becomes imperceptible.

Spallanzani examined them with minute attention with the assistance of a magnifying glass, but he could not detect any action of breathing. Their respiration becomes suspended at 55°, and at 47° they certainly live without any perceptible breathing. Torpid bats lived

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* Rapports de l'Air, &c. tom. ii. p. 215.

seven

seven minutes within the exhausted receiver of an air-pump, in which another bat perished at the end of three minutes. Spallanzani also relates that he placed torpid marmots in vessels filled with carbonic acid and hydrogen gas, and confined them there for four hours without doing them the least injury, the temperature of the atmosphere being several degrees below the freezing point; but he found that, if these animals were awakened by any means, or if the temperature was not low enough to produce complete torpor, they very soon perished in the same noxious gases*.

A bird and a rat introduced into a receiver containing carbonic acid gas, did not live a minute, whereas a torpid marmot remained in it an hour without be-

* Rapports de l'Air, &c. tom. ii. p. 207.

traying

traying the least desire to move, and recovered perfectly on being placed in a warmer medium. Four and five cubic inches of atmospherical air was not at all changed in its properties after torpid bats and marmots had remained in it three hours.

During the severe winter of 1795, this ingenious philosopher made similar trials upon dormice, with similar results. After being exposed to a temperature below the freezing point, they remained inclosed in vessels filled with carbonic acid and azotic gas over mercury three hours and a half without being hurt, and the sides of the vessels were not marked by any vapour: hence we may conclude that they did not breathe, nor give out any carbonic acid gas.

Amphibious animals never become so completely torpid as the quadrupeds before

fore mentioned, notwithstanding their being exposed to as great a degree of artificial or natural cold : hence they perish after a certain time, and that of no long duration, in unrespirable gases. Caterpillars cease to respire at 32°: they consume only one fourth part of the oxygen at 36°, which they require in a higher temperature : at 46° they cease to eat, and whilst the thermometer stands at that point during the night, or even eighteen or twenty degrees higher in the daytime, they no longer undergo their usual transformations. Thus Reaumur prolonged the life of many insects by keeping them exposed to a certain degree of cold, and Spallanzani prolonged the existence of frogs and serpents for three years and a half, by the same method continued for that space of time.

My friend Dr. Smith, the learned President

sident of the Linnæan Society, informs me that he observed that the respiration of a tortoise kept in a room in London was always slower in winter than in summer; and I have remarked the same circumstance in attending to the habits of dormice, marmots, bats, and hedgehogs.

IV. *The action of the stomach and digestive organs is suspended.*

This appears from some experiments of Mr. Hunter, and is further confirmed by observations of Pallas, Spallanzani, and others. The first of these distinguished naturalists introduced food into the stomachs of lizards going to hybernate, and upon opening them at different periods, the aliment was found unaltered, sometimes in the stomach, sometimes in the intestines; and after the period of hybernation it was thrown out unchanged

unchanged either by vomiting or by the bowels.

Marmots, dormice, and bats remain in their wild state four and five months without taking any food; their intestines are quite clear before the torpidity begins, and are found empty after they first awake in the spring.

Dr. Monro kept a hedgehog in a room without a fire at Edinburgh, from the month of November till March. About the beginning of December, the animal was affected with an unusual degree of drowsiness, he continued however to eat, though more sparingly, till the twenty-fifth of that month. From that time till the eighth day of March following, he continued in a profound sleep except when artificially roused, and after being so disturbed he soon returned to his place of retreat and resumed his dormant state.

state. Some small quantity of urine and fæculent matter was observed among the hay; but in the course of three months the animal did not appear to have eaten or drunk, although food was constantly placed near it. Its limbs were never rigid, and it lost during the torpor two ounces of its weight*.

The polar bear is said to continue for six weeks in the depth of winter without provision, and is supposed to remain asleep, or totally inactive†. A land-tortoise kept by Mr. White of Selborne for forty years was very voracious during the summer, but gradually became less and less so; and before it grew torpid, which was regularly in the middle

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* Smellie's Philosophy of Natural History, vol. ii. p. 410.

† Pennant's Arctic Zoology, vol. i. p. 59.

of

of November, it hardly ate anything. The poet Martial makes the dormouse say,

"Tota mihi dormitur hyems, et pinguior illo
Tempore sum, quo me nil nisi somnus alit."

But this is a poetical fiction; for the fact is, that the dormouse undergoes very little alteration during the winter, yet it does lose some weight; and although the marmot is often found extremely lean in the spring, after recovering from its lethargic state, that leanness is in consequence of its not being able always to find food enough for its consumption. I have been repeatedly assured by men who hunt for these animals in winter, that they are always found fat in their holes on the mountains of Switzerland, and it is only when they come out of their hiding-places before provisions are ready for them, or if a sharp frost should occur after some warm weather, that they become

become emaciated and weak. Mr. Cornish indeed remarks that both dormice and bats lose from five to seven grains in weight, during a fortnight's hybernation*, and I find some collateral proofs of this assertion in the works of Spallanzani,—but these alterations are in consequence of some actions occasionally excited by interrupted sleep.

It sometimes happens that some hybernating animals kept in warm rooms, do not become torpid at the temperature which would have rendered them so if they had been at liberty. The great processes of life, the respiration, the circulation, and the nutrition, are not interrupted in these instances; and here we may notice a remarkable difference between the viviparous and oviparous qua-

* Daines Barrington's Miscellanies, p. 167.

drupeds,

drupeds, since the latter become torpid in every possible situation and in all circumstances when exposed to the proper degree of cold, and remain so as long as they are kept in that condition. Spallanzani discovered this fact by keeping some species of these quadrupeds in a temperature between 38° and 39°, for three years and a half, without food; when they recovered their vital actions and original vivacity in the month of May, on being put into a reservoir of water, where they multiplied.

Lastly, *The irritability and sensibility of the muscular and nervous powers are diminished and suspended.*

The irritability of hybernating animals is affected in the same way as their temperature; it follows the same laws in the gradual loss of its energy, and appears

pears to be influenced by the same causes, until it becomes imperceptible, when the torpor is completely established: the strongest stimuli then make no impression on them.

Marmots are not roused from their torpid state by the electric spark strong enough to give a smart sensation to the hand, and a shock from a Leyden phial only excited them for a short time, as Spallanzani has related in his experiments made upon them with Alexander Volta. They are insensible to pricking their feet and nose, and remain motionless and apparently dead. Bats also are insensible to every kind of stimulus except heat, or to a stream of air blown upon them, which affects their sensations powerfully.

Wounds have been inflicted and limbs broken, without the mutilated animals expressing any signs of pain, so much is their

their sensibility diminished by the action of the cold. It is the same with their muscular power: no traces of voluntary motion can be discovered, and they are rolled up into a shape to preclude all locomotion except what they receive from external force.

To illustrate these several assertions by a greater number of experimental proofs, or by a more elaborate detail of facts, appears to me unnecessary: those who are curious to become more intimately acquainted with the particular experiments upon this subject, may have recourse to the Memoirs on Respiration by Spallanzani, so often alluded to: there illustrations abound, and I have only selected such as seemed to me to bear particularly on each of the points which I have been desirous to establish.

SECTION

SECTION II.

CAUSES OF TORPIDITY.

After this statement of the principal facts relating to the hybernation of animals, I proceed to offer some general remarks on the causes which induce it.

The most obvious distinction between those animals which hybernate and those which are able to resist the action of cold is the difference of their internal temperature, and the circumstances connected with that difference. While the latter possess a temperature much higher than the medium in which they are placed, and in some measure independent of it, the former differ from the surrounding medium only a few degrees,

and are so much influenced by it as to vary with all its variations.

The tribe of quadrupeds have the habit of rolling themselves into the form of a ball during ordinary sleep; and they invariably assume the same attitude when in the torpid state, so as to expose the least possible surface to the action of cold: the limbs are all folded into the hollow made by the bending of the body: the clavicles and the sternum are pressed against the fore part of the neck, so as to interrupt the flow of blood which supplies the head, and to compress the trachea: the abdominal viscera and the hinder limbs are pushed against the diaphragm, so as to interrupt its motions, and to impede the flow of blood through the large vessels which penetrate it, and the longitudinal extension of the cavity of the thorax is entirely obstructed.

Thus

Thus a confined circulation is carried on through the heart, probably adapted to the last weak actions of life, and to its gradual recommencement.

Mr. Carlisle very justly observes, in his original and able lecture on muscular motion *, that "animals of the class *Mammalia*, which hybernate and become torpid in the winter, have at all times a power of subsisting under a confined respiration, which would destroy other animals not having this peculiar habit. In all the hybernating *Mammalia* there is a peculiar structure of the heart and its principal veins: the superior cava divides into two trunks; the left, passing over the left auricle of the heart, opens

* The Croonian Lecture on Muscular Motion, by Anthony Carlisle, Esq. F. R. S., Phil. Transactions, 1805.

into the inferior part of the right auricle, near to the entrance of the vena cava inferior. The veins usually called azygos accumulate into two trunks, which open into the branch of the vena cava superior, on its own side of the thorax. The intercostal arteries and veins in these animals are unusually large."

An anonymous author, who transmitted a memoir upon this subject to the National Institute at Paris, gave some anatomical details respecting the diaphragmatic nerves, and those known under the name of nerves of the eighth pair, and also concerning the thymus gland*; but excepting a mass of glandular substance in the marmot, and large portions of omentum, I have never been able to discover any remarkable dif-

* Philosophical Magazine, vol. xiv. p. 88.

ference

ference in the structure of hybernating animals; admitting, however, most fully those peculiarities which Mr. Carlisle has so well pointed out.

In the class of *Amphibia*, we find a difference in the structure of the organs subservient to the two great functions, respiration and circulation. The heart in these animals has but one ventricle, the pulmonary arteries are only branches from the aorta. The tortoise, however, has two ventricles, as the *Mammalia* and *Aves*; but there is a communication between the right and left, and the blood passes freely from one to the other; only a small portion of the blood, therefore, comes in contact with the air in the lungs; and the circulation may be carried on, every part of the body may receive its due portion of blood, while the lungs are in a state of collapse. These animals

mals consume less oxygen in a given time, in proportion to their size, than birds or quadrupeds; but they absorb oxygen by their skin in their natural state, although, when torpid, the consumption of oxygen in both these ways is suspended. Hence we can account for their diminished temperature, and hence in all probability the weakness of their sentient organs arises.

Pallas, the celebrated naturalist, remarked long ago that hedgehogs, marmots, and the whole tribe of *Glires*, become very fat during the summer, and are furnished with several omenta in the abdomen; and besides, having the thymus gland larger than usual, they have two glandular bodies resembling the thymus, under the throat and upper part of the thorax, which appear particularly florid and vascular in their state of hyber-

hybernation*. It has been inferred from this and from some other facts of a similar kind, that fatness is one of the predisposing causes of hybernation; but Spallanzani observed that, among the dormice which were caught for his experiments, some of them were fat and some lean, and yet they were equally susceptible of the action of cold. The accumulation of fat, therefore, is an accidental occurrence, and not a necessary cause. We find many kinds of insects and animals become torpid in winter without any provision of this nature.

Here a curious question arises respecting the disappearance of birds. It is singular that this subject should still ad-

* Pallas, Nov. Comment. Petrop. vol. xiv.; and in his admirable work, Novæ Species Quadrupedum e Glirium Ordine.

mit of doubt, when it seems so easy to be decided; yet every month we see queries and answers about the migration of swallows, and every year our curiosity is tempted to be amused with marvellous histories of a party of these birds diving under water in some remote quarter of America. No species of bird, except the swallow, the cuckow, and the woodcock, have been supposed to remain torpid during the winter months. And what is the evidence in favour of so strange and monstrous a supposition? Nothing but the most vague testimonies, and histories repugnant to reason and experience.

Daines Barrington, an ingenious man and a well-informed naturalist, took great pains, about forty years ago, to collect the best authorities on the disappearance of swallows, and he decides in favour of their

their torpidity during winter. But all the histories which he details are expressed with the same degree of wonder, and related with the same degree of inaccuracy. The want of some decisive experiments is very much to be regretted: in the mean time, our minds are apt to be imposed upon by the nature and apparent difficulty of the subject; and persons who think themselves unequal to the labour of investigating an intricate point, or who wish to avoid it, are ready enough to believe that much has been proved because much has been said.

There is scarcely a treatise on ornithology which does not allude to the submersion of swallows during the winter, as a fact almost as well known as their flying in the air during the summer; and the great authority of Linnæus has given credit and currency to this

this opinion. His words are, "*Hirundo rustica habitat in Europæ domibus intra tectum, unaque cum urbica demergitur, vereque emergit.*" His authority extends also to martins; and it is clear from the expressions used in the definition, that Linnæus conceived that these birds concealed themselves under water during the winter; and we find in the dissertations read before the academy of Upsal, that the submersion of swallows was received as an acknowledged fact in Sweden.

Klein, in his Historiæ Avium Prodromus, endeavours to prove that swallows do not migrate, but retire under water at the time of their disappearance, and remain torpid all the winter: he relates many attested instances of their being so found in the northern parts of Germany.

If all birds, except swallows, are able

to

to survive the winter, and they alone are so overcome by the cold as to be rendered torpid, the difference must be found in their anatomical structure and in their habits of life.

Now, in the first place, it is certain that they have, in common with other birds, the three great functions of respiration, circulation, and assimilation: the similarity of their organs and every circumstance in their mode of living prove that they are subject to the same laws: they have also a very high temperature; and are peculiarly organized for rapid and long flight. The size of their lungs, the lightness of their bones, and the buoyancy of their feathers, render it absolutely impossible to sink them in water without a considerable weight, and they die instantly for want of air.

Swallows

Swallows are said to assemble on reeds and on the banks of rivers, and to sing their *swallow song* before they dive under water; but none were ever found in all the rivers and lakes of England, Wales, Ireland, Scotland, or Switzerland, although fishermen are constantly employed on these their supposed hiding-places. They assemble in numbers, and are supposed voluntarily to become torpid in the month of September; they disappear at a time when the temperature of the air is not cold enough to produce any effect upon the tribe of hybernating animals; and besides, it is quite contrary to all reason and experience that these birds should have their respiration and other functions suspended suddenly without material injury.

Other birds are admitted to migrate, and why should swallows be exempt from

from this general law of their nature? When food fails in one quarter of the world, their instinct prompts them to seek it in another. We know in fact that such is their natural habit: we have the most unexceptionable proofs that swallows do migrate; they have been seen at sea on the rigging of ships; and Adanson, the celebrated naturalist, is said to have caught four European swallows fifty leagues from land, between the coast of Goree and Senegal, in the month of October*.

Spallanzani saw swallows in October on the island of Lipari, and he was told that when a warm southerly breeze blows in winter they are frequently seen skimming along the streets in the city: he concludes that they do not pass

* Adanson, Voyage au Senegal, p. 15.

into

into Africa at the approach of winter, but remain in the island, and issue from their retreat on warm days in quest of food *.—I do not find that he has anywhere fulfilled his promise of publishing the observations he made on the swallows of Lipari and Sicily; but, as he excludes these birds from his experimental researches on hybernation, I take his silence as conclusive evidence against the truth of the vulgar opinion concerning them.

The late Peter Collinson detected the fallacy of the common notion about the submersion of swallows: in his interesting correspondence with Linnæus, he repeatedly urged him to bring the matter to a decisive issue, by proposing some questions, and pointing out an easy

* Travels in the Two Sicilies, vol. iv. p. 115.

method

method of having them answered. As Linnæus did not take any notice of these questions for a long while, although he was strongly called upon at different times by his acute correspondent, we may fairly infer that he was unable to give any satisfactory answer; and his constant evasion of the experimental proofs is an indication of his being unprepared to support what he had asserted, by any thing more than the common authorities.

I have known several attempts made to keep swallows in a warm room during winter, but without success; they seemed to die for want of their accustomed food, which cannot be procured at that season of the year. Excess of cold, disappearance of insects, heavy showers of rain, falling of the leaves, absence of fruit, freezing of the surface of the waters, are some of the principal causes

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of the annual migration of many kinds of birds. We may consider swallows as belonging to these tribes, which form an intermediate class between hybernating animals and those which are able to withstand the most rigorous climate, and we observe how obedient they are to the great laws of procuring food and avoiding pain.—In Siberia birds must frequently endure cold below 0°, as the thermometer is often in winter 50 degrees below that point according to Gmelin's account of that country; and we find sparrows and other small birds in our own country able to endure very severe cold without any tendency to become torpid, because they are still able to procure food.

The phænomena of torpidity corroborate strongly the truth of the theory which attributes animal temperature to

to respiration. We have already seen that, during this state, the respiration becomes slower, and ceases altogether; the pulse is less frequent, and the temperature of the body diminished. The sources of combustible matter are cut off; but since the temperature is higher than that of the atmosphere, there must be some combustion going on, and this is supplied by the fat, which is absorbed, and supplies the hydrocarbon which affords the small quantity of caloric evolved by these animals.

Diminished respiration is the first step in the series of actions which accompany this state of torpidity: confined air and interrupted breathing always precede the phænomena; the animal retires from the open atmosphere into some cavern or hole under ground, his mouth and nostrils are brought into contact with his

chest and enveloped in fur, he falls into a profound sleep, and becomes cold and insensible.

A singular circumstance related by Pallas of the hamster (*Mus cricetus* Linn.) places this subject in a striking point of view. The hamster is about the size of a rat, and inhabits the plains of Russia, Siberia, and Germany; it becomes torpid in the winter; but cold alone does not produce the torpidity,—it must be excluded from the air. When inclosed in a box filled with earth and straw, it never becomes torpid, however great the degree of cold to which it is exposed, unless the box be buried four or five feet under ground, and earth thrown over it to exclude the access of air: if it be examined about eight or ten days after, the animal is found as completely torpid as in its natural hole; and if it be exposed

posed then in the open air to a greater degree of cold than what it experienced in the box, it is roused, and awakes in a few hours; but falls into the state of torpor again on being placed beneath the surface of the earth in the same manner as before: the light does not tend to rouse the animal, since it is equally awakened on being exposed to the air during the night.

I may here remark that I met with an accident at Vienna in the month of December 1805, which corroborates what is commonly alleged concerning the hamster. A hamster, kept in a small cage and in a room where a fire was lighted every day, ate very heartily and appeared in good health for several months, without showing any signs of torpidity, except remaining rolled up in coarse wool and dried leaves, and only coming

out once or twice a day to eat his food ; one cold night he died, and on examination no cause could be discovered ; I therefore attributed his death to the want of that confined air which is so essential to their torpidity, and consequently to the preservation of their life. It is worthy of notice, that the weather was remarkably sharp at the time when this hamster died ; the marmots which I kept became more torpid than I had ever before seen them, and two young hedgehogs, in the same room without a fire, died the same night.

Hence it appears that although diminished respiration and diminished temperature be the first causes, they are not the only circumstances which influence torpidity ; and the degree of diminution has not the same effect on all kinds of animals. Bees, for instance, become tor-

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pid at a temperature which does not affect the other classes of animals: and we find that removing animals into a colder medium, whilst they are in a torpid state, instead of increasing, rouses them from their torpidity.—It is the temperature which affects the respiration of cold-blooded animals and prolongs the suspension of it: frogs, salamanders, and snakes have lived for three years and a half in an ice-house, in the same torpid state as that to which they are subject every winter: and Spallanzani has observed hybernating animals, which lived in an atmosphere of noxious gas at a low temperature, die instantly as soon as the temperature was raised above that at which the respiration of these animals ceased.

The effects of low temperature on the respiration, on the circulation, and on the

the muscular and nervous powers are so simultaneous, or so closely connected together, that it is difficult to attribute to any one the influence resulting from a strong action upon them all.—However, the experiments of Spallanzani prove most decisively that the blood is not particularly concerned in producing torpidity, because it does not congeal in hybernating animals, although it is exposed to a degree of cold sufficient to freeze it: frogs and salamanders deprived of their blood become torpid by a low temperature, and recover again on its being raised.

Neither the lungs, the heart, nor any of the abdominal viscera, nor the nerves have any influence upon the torpidity of frogs, salamanders, and snails, because they are equally affected by cold and heat in winter, after being entirely deprived

prived of those parts, and even after the brain and spinal marrow are destroyed.

The cessation of muscular action seems owing to the lowered temperature of the muscles themselves, because, when the transmission of nervous influence is prevented by dividing the nerve and destroying the brain, the irritability is suspended and recovered exactly in the same manner by the operation of cold, as in the ordinary state of torpid animals. The loss of motion and sensation, therefore, is owing to the diminished irritability of the muscular fibres, and that again is caused by the action of cold, and by suspended respiration; the capillaries of the vascular system appear to become contracted by the loss of animal heat; and this diminution always begins at the surface of the body and gradually increases to the centre, as observed

served in examples of numbness from cold, and in applying the thermometer to different parts of animals whilst they are gradually becoming torpid. We see these animals resist the propensity to torpor, until by the gradual diminution of their heat, and the want of a supply from the absorption of oxygen at their lungs and at the surface of their bodies, the irritability is so far lessened that it becomes itself a cause of its own deficiency by arresting the respiration, and consequently depriving the heart of its supply which is furnished by the coronary arteries. It is probable that the influence of cold not only prevents the absorption of oxygen, but interrupts its decomposition and union with the fibrin of the blood and muscular fibres; facts which accord with the phænomena of hybernation, where an increase of temperature is inseparably

inseparably connected with absorption of oxygen, increased irritability, and acceleration of the action of the heart.

Whatever may be the precise nature of actions induced by cold upon hybernating animals, the nervous system seems in the first instance to be affected, and the equilibrium which in health subsists between the nervous and muscular power, is then destroyed. But the numbness and cold do not derange the relation between the solids and fluids, nor impair the vital powers so far as to destroy their state of combination; for if the muscular fibres be frozen and the blood congealed by excessive cold, then the animals perish.

The effect of cold on our nervous system is shown by the tendency to sleep produced by exposure to a very cold atmosphere in certain situations. This

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is very different from natural sleep, and nothing will prevent its taking place but being removed to a higher temperature; nor can the propensity sometimes be resisted, although the person is well aware of the fatal consequences of indulging it.

A striking illustration of this fact is recorded in captain Cook's voyage, with respect to Dr. Solander, whilst exploring Terra del Fuego, in company with sir Joseph Banks and others: he was so perfectly aware of the consequences of giving way to sleep that he cautioned his companions against it, and yet could not himself overcome the desire to sleep.

This curious fact is still further corroborated by an interesting account of the action of cold upon the French soldiers in their passage over the Alps in the memorable

morable campaign of 1795*. The comatose state, the loss of sense and motion, arose from the direct operation of the cold air upon the men after considerable fatigue and exhaustion; and what shows incontestably that the nervous system was affected and not the circulation, is, that all those who were fortunately recovered by medical aid had none of their limbs injured by that species of mortification or congelation so well described by the French writers.

On the top of Mount Blanc this strong propensity to sleep is produced; one of M. De Saussure's guides actually fell

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* See "Observations Médicinales sur les principaux Effets du Froid et du Chaud sur le Sommet des hautes Montagnes: par les cit^s. Parat et Martin."—Recueil des Actes de la Société de Lyon, 1798.

asleep

asleep involuntarily: but besides the low temperature, something in this instance may be attributed to the rarefaction of the atmosphere, since persons who have ascended in balloons have felt very drowsy, and some have slept in such situations.

SECTION

SECTION III.

ON THE VARIETY OF TEMPERATURE IN DIFFERENT CLASSES OF ANIMALS.

It will not, I trust, be deemed a digression foreign to the professed object of this Essay, if I here make a few observations on the variety of temperature in different classes of animals; as the result will show how much influence respiration has upon the muscular and nervous power, and how intimately connected are the laws of the animal œconomy.

In man, the temperature is subject to very little variation; it varies, however, a few degrees in disease, but in circumstances where it is affected most, the variation bears no proportion to the changes

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in the temperature of the surrounding medium, nor to the sensation of heat which the increased or diminished temperature would seem to convey. When placed in a high temperature, the heat of the human body, whilst alive, is lower than that of the surrounding medium: when in a low temperature, it is higher.

This principle has been extended through all classes of animals, and even to plants; and in consequence of this extension it has been considered as one of the most essential properties of life; but it does not appear so essential as the relation between different particles in the complicated mass of solids and fluids, which constitutes muscular motion and sensation. It is regulated by the process of respiration and the introduction of hydrocarbon; it is not, therefore, a simple effect of the living principle, but

depends

depends on the due performance of the animal functions.

The temperature is most stable in those animals which consume the most oxygen, and it ceases to be so, when they lose the power of consuming oxygen and the power of digesting food, as during their torpid state. Those animals which consume the most oxygen, longest resist the action of freezing mixtures ; hence the power of resisting cold seems to depend in a great measure on the degree of combustion.

Birds have a higher temperature than any other class of animals ; it is from three to six degrees higher than that of quadrupeds. It has been remarked that the respiring organs of birds are larger in proportion than those of quadrupeds ; though the lungs, properly so called, are not

not very large, they communicate with air-bags in the abdomen and with cavities in the bones; and when these bags are compressed or dilated, the air passes over the surface of the lungs. Mr. Hunter conjectured that these cavities serve as reservoirs of air during the long flights which they take; and they have also been supposed to assist their flying. There are no very accurate experiments on the consumption of oxygen by birds; but Dr. Higgins has remarked that they consume more oxygen than animals of the same size, and Blumenbach relates that he placed two sparrows and two frogs in the same quantity of gas; the two former were killed before the latter were at all affected.

Fishes and amphibia have a temperature little exceeding that of the surrounding

rounding medium; hence the division into warm-blooded and cold-blooded animals: but when these animals are placed in a high temperature, their thermometrical heat is somewhat lower than that of the surrounding medium; hence those terms are only relative.

The temperature of insects, like that of fishes, is little above that of the surrounding medium; they have no pulmonary organs like other animals; they have only small oval holes over the body, called by naturalists *Spiracula*; which are the orifices of canals or tracheæ, distributed to every part of the body, and communicating to it a portion of air. The bee differs from other insects in having its temperature nearly equal to that of quadrupeds. Perhaps this is in consequence of bees being gregarious,

garious, for the heat of the hive is great even in very cold weather. In spring it is from 93° to 98°; in summer 104°; when the external temperature is 40° that of the hive is 82°: and Mr. Hunter found the temperature 73° in the winter season. The bee consumes the greatest quantity of honey when the weather is cold, that is, when it wants most combustible matter.

Boerhaave laid it down as an aphorism, that an animal could not live long in a temperature superior to its own standard: but this idea has been proved to be erroneous, because in many places the summer heat exceeds it. At Bussorah the thermometer in the shade, in the month of June, stood at 115°, sometimes higher; and a remittent fever was the only epidemic disease that appeared. In Finland

land and Russia the inhabitants expose themselves in vapour baths, to a temperature from 110° to 140°, without having the temperature of their bodies raised above 104°, and without injury.

The facts which first overturned Boerhaave's doctrine were related by Duhamel and Dutillet before the Royal Academy at Paris. They observed that the maid-servants of a baker could venture into an oven heated to 276°, and remain there a quarter of an hour: they themselves remained nearly five minutes in a temperature equal to 290° of Fahrenheit*. These experiments, which excited considerable interest among philosophers,

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*Duhamel, Supplément au Traité de la Conservation des Grains.

Dutillet, Traité du Dégré de Chaleur auquel les Hommes et les Animaux résistent.

have been confirmed by sir Charles Blagden, Dr. Fordyce, and others, who remained a long time in a very high temperature, without the temperature of their bodies being raised more than three or four degrees.

This uniformity of temperature was attributed to a power in the living body of generating cold; by which expression nothing can be understood but the carrying off caloric, or its conversion from a sensible to a latent state. Whether the evaporation or the common processes of cooling were increased, is not known, for the relation of these experiments is defective in the most material points; and nothing more can be deduced from them, than that at so high a temperature the temperature of the surface of the human body was increased only about three degrees, and we may conclude that the

temperature

temperature of the whole was increased to the same standard.

By these experiments, and by other histories which might be related, the general fact is ascertained, that life may be sustained under a great increase of temperature in the surrounding medium; and experiments equally prove that life may be sustained under a considerable reduction of temperature.

In Dr. Currie's experiments on the effects of cold upon persons in health, they were immersed in salt water at 40°, and the thermometer under the tongue fell to 90° and 88°, but presently rose to 96°, and then became stationary. The shower bath produced little alteration on the thermometer, rather a rise than a fall of the mercury: however, when fresh water was used the effects were very different, the thermometer sunk

sunk to 92°, sickness was produced, and a febrile attack, which was soon removed by sweating.

Some experiments were made at Edinburgh, and published by Dr. Spooner in his Thesis "De Ascite Abdominali," 1785; which prove that exposure to cold has the effect of diminishing the force of the pulse very much, and of producing anasarca, as the uniform effects of being exposed naked when the temperature of the air was 32° upon Arthur's Seat, were accumulation of blood in the extreme vessels, great exhaustion, and effusion into the cellular membrane.

"It appears," says Mr. Carlisle, "that all classes of animals are endowed with some power of producing thermometrical heat, since it has been so established in the amphibia, pisces, vermes, and insecta,

secta, by Mr. John Hunter, a fact which has been verified to my own experience*." Notwithstanding two such high authorities, I am disposed to think that animal temperature depends wholly on respiration; and as we have no means of estimating the ratio of any other power, which in the examples above mentioned is not sufficient to preserve their equable temperature in cold climates, we may conclude that it is the difference in the function of respiration which regulates this important process in the animal œconomy; and the peculiar power possessed by the abovementioned animals, and by some of the *Mammalia*, is that of yielding to the changes of the atmosphere and becoming torpid during the winter.

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* Lecture on Muscular Motion, Phil. Trans. 1805, p. 15.

Among

Among the great variety of situations in which hybernating animals are found, it has been asked, What is their natural state? and it has been answered that Torpidity is not their natural state, not a constitutional principle of their animal œconomy, not a necessary propensity, but a habit accidentally produced by external circumstances. This, however, is an abuse of language, for the proper meaning of words authorizes us to consider that as the natural state, which an animal would assume, if it were placed upon the earth and left without food to the spontaneous impulse of nature;—and in this point of view, the state of torpidity is strictly a natural and instinctive habit.

There are some facts which have been brought forward in support of the opposite opinion; but they seem to me, if they

they prove any thing, to prove too much, because they show how much is effected by the principle of accommodation that regulates the animal œconomy, and how the natural habits may be altered by domestication.

A tame marmot kept by Pallas, which became extremely fat during the summer, continued awake the whole winter, although it was exposed to the same low temperature which threw the whole species into a torpid state in that part of Siberia. Mr. Gough observed several years ago that the dormouse may be prevented from becoming torpid, by supplying it plentifully with food. And I have observed the same circumstance with regard to the hedgehog; when kept in a warm house and supplied with food, it is able to resist the action of severe weather without showing any disposition

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to become torpid. I am disposed to think the torpor of the hedgehog is never so complete as that of other animals; Spallanzani was not able to produce torpor by artificial means, and he never saw a hedgehog in its torpid state; but there can be no doubt of its being torpid, when left to itself in a wild state, and the only difference is that it is easily prevented by a generous diet.

That torpor is natural to some animals appears evident, since they cannot live through the winter without it, as exemplified in the jerboa.

Gmelin says that all the species of Dipus hybernate, "*Myoxi omnes hybernant et dipodes**." This assertion, however, is too general, because many of

* Systema Naturæ, tom. i. p. 157.

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the same species of animals which become torpid in one country, do not become so in another. In the United States of America this fact is very observable. Many species of animals which hybernate in Pennsylvania, and other more northern parts of the country, do not become torpid in the Carolinas and other southern parts of the continent*.

It has been supposed that hybernating animals were originally inhabitants of warmer climates, driven from thence by want of food or by accidental causes, and compelled to seek for safety in colder regions. The hypothesis cannot be decided for want of observations, as we are still ignorant respecting many parts of the natural history of these ani-

* Dr. Barton's paper in American Phil. Trans. vol. iv.

mals;

mals; for instance, What is the native country of each species of hybernating animal, and what the temperature of its climate? Would the animals which become torpid every winter in this country, assume the same habit in a warmer latitude? Would serpents and lizards, which live between the tropics, become torpid in our climate at the approach of winter? Is there any thing in the anatomical structure of hybernating animals which points out a marked difference between them and other tribes, and shows their destination? Are they endowed with a longer life than other animals?—Inquiries of this sort would throw considerable light on their singular mode of existence, and we might be led to some interesting and useful knowledge, by a series of well-attested facts and experiments on each of these questions.

At

At the very time when all the different animals become torpid in our quarter of the world, their food is no longer to be procured; they would perish by hunger, if a supply of food were not rendered unnecessary by a suspension of their animal functions; and these actions are not restored till the spring, when the same sun, whose vivifying influence awakens them, acts in like manner upon the larvæ of insects, and the seeds and roots of plants, in order to furnish the necessary supply of food for the reviving animals as soon as they require it.

When the phænomena of torpidity are first presented to the mind, astonishment and perplexity arise, because they appear inexplicable: torpid animals appear insulated beings; they seem to form an exception to our general ideas of animal existence, in which we naturally look

look for motion, activity, and change. But after tracing the regular gradations in nature, and observing the intimate connection and relation of the various species of organized beings, our wonder may cease, whilst our admiration of the infinite wisdom and goodness of the Creator must be elevated and increased. This is not the only fact which at first appears an exception to a general law, it is not a solitary instance of that beautiful accommodation of intricate means for simple ends;—in reading the works of Réaumur, Trembley, Bonnet, and Spallanzani, numerous examples equally surprising may be found.

Buffon thought that torpid animals suffered their animation to be suspended, from their not being able to evolve heat sufficient to keep them in the same temperature as the external air: but in this

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he was completely mistaken; for, notwithstanding all attempts to diminish their temperature, it still continues above that of the atmosphere in which they are placed.

Mr. Du Pont de Nemours, in an ingenious memoir on a kind of death that may be presumed to be only apparent, adopts the following opinion, perhaps with the majority of naturalists, respecting the nature of torpidity: he refers it partly to the benumbing effects of the cold which prevails in the winter, and partly to a high degree of corpulency, which is generally contracted in autumn, from an unrestrained indulgence in the abundance and delicacies of that season. He moreover supposes that animals do not submit to this long suspension of their vital functions in obedience to the dictates of necessity; on the contrary, he

he imagines them to court a lethargic habit, in consequence of certain pleasing sensations which are known to precede the first moments of sleep.

To this hypothesis Mr. Gough has very ably stated some objections, and he substantiates them by facts which are new and interesting, the results of his own acute observation. His objections are contained in the four following propositions; I shall state them in his own words*:—

"First, Animals do not submit to torpidity upon choice, but from necessity: and when cold happens to be the immediate cause, they fly from it, if possible.

"Second, Certain animals apparently

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* Nicholson's Journal of Nat. Phil. and Chemistry, vol. xix. p. 162.

support

support a voluntary suspension of their functions in summer as well as winter, when food is withheld from them: this is probably intended to preserve life by diminishing the action of the system.

"Third, A quadruped noted for its lethargic disposition in winter may be so far strengthened by a generous diet as to retain the full use of its faculties during the time of a severe frost: from which we may infer that an emaciated habit of body is the predisposing cause of torpidity, in opposition to the common opinion which assigns this office to corpulence.

"Fourth, The united action of hunger and a low temperature has produced a kind of apparent death in a human being, who was restored to life by stimulating remedies, after lying several days without sense and motion.

"The hearth cricket (*Gryllus domesticus*) affords a proof of the first objection. Those who have attended to the manners of this familiar insect will know that it passes the hottest part of the summer in sunny situations, concealed in the crevices of walls and heaps of rubbish. It quits its summer abode about the end of August, and fixes its residence by the fire-side of the kitchen or cottage, where it multiplies its species, and is as merry at Christmas as other insects are in the dog-days. Thus do the comforts of a warm hearth afford the cricket a safe refuge, not from death, but from temporary torpidity; which it can support for a long time, when deprived by accident of artificial warmth.—I came to the knowledge of this fact," says Mr. Gough, "by planting a colony of these insects in a kitchen, where a constant fire is kept through

through the summer, but which is discontinued from November to June, with the exception of a day once in six or eight weeks. The crickets were brought from a distance, and let go in this room in the beginning of September 1806: here they increased considerably in the course of two months, but were not heard or seen after the fire was removed. Their disappearance led me to conclude that the cold had killed them: but in this I was mistaken; for, a brisk fire being kept up for a whole day in the winter, the warmth of it invited my colony from their hiding-place, but not before the evening; after which they continued to skip about and chirp the greater part of the following day, when they again disappeared; being compelled by the returning cold to take refuge in their former retreats. They left the

chimney-corner on the 28th of May 1807, after a fit of very hot weather, and revisited their winter residence on the 31st of August. Here they spent the summer merely, and lie torpid at present (Jan. 1808) in the crevices of the chimney, with the exception of those days on which they are recalled to a temporary existence by the comforts of a fire."

In addition to the above illustration, I think the first objection may be exemplified by the well-known fact of the migration of animals. Some species of *Dipus* migrate from the northern to the southern parts of America, others remain stationary and torpid during the winter. Spallanzani discovered that a great number of the species of bats, especially *Vespertilio murinus*, migrate at the approach of cold weather in Italy.—At Pavia there are no grottoes nor caverns where

where bats could retire; yet not a single *Vespertilio murinus* could ever be found in winter, though no pains nor expense were spared in searching for them. The last time bats were seen by Spallanzani at Pavia was the 2d of November, when the thermometer was at 55°.—Another species (*Vespertilio equinus*) was seen at Modena on the 4th of the same month. In the beginning of March, when the thermometer was at 45°, several kinds of bats were seen flying about in the neighbourhood of their hiding-places: not one of *Vesp. equinus* yet appeared; the weather being too cold for them, since some species are quite torpid at a temperature which others are able to endure without their muscular energy being diminished. One singular circumstance Spallanzani noticed in caverns where bats were collected in groups on the cieling: they

they remained suspended by their claws even in their torpid state, and he saw them in that situation even after they were dead *. Their claws and their muscles must be said to be in a state of repose, and to be disposed in a way to retain the same posture, even in this state of suspension: just as some birds sleep, supported on one leg only. Some kinds of bats certainly migrate, and it is not the degree of cold that urges their removal from one place to another, because they return in the spring to the spot which they left when the thermometer is lower than it was at the time when they quitted it; so that it is most probable that want of food urges them to migrate, and if any species remain

* Rapports de l'Air avec les Etres Organisés, tom. ii. p. 125.

behind,

behind, it is because they can still find insects which serve as food.

The second objection is exemplified by Mr. Gough in the following manner: "I took," says he, "several specimens of the garden snail, *Helix hortensis*, and shut them up in a perforated wafer-box, which secluded them from food and water, but not from air. A number of the *Helix zonaria* were treated in the same manner; and a few of this species were put into a bottle, which was corked to cut off all communication with the atmosphere, as well as food and water. Those snails did not live long which were deprived of air; but the specimens of both species did not die which were confined in the perforated boxes. On the contrary, they retired into their shells, closing the apertures of them with thin

thin membranes; here they remained dead to all appearance, as long as I kept them dry. But this death was nothing more than apparent; for I restored my prisoners to life in succession, by dropping them into a glass containing water of the temperature of 70° or 72°: after leaving them four or five hours in this situation, I constantly found them alive, and sticking to a plate which covered the vessel. A large garden snail supported this severe confinement nearly three years, being apparently dead all the time; after which it revived upon being put into water, like the rest of its fellow captives. This wonderful faculty, however, is not possessed by snails of every description."

There are other instances of suspended animation, resembling in some respects the torpidity of warm-blooded animals, which

which some animalcula afford, as the wheel-animal, the sloth, the anguillæ of tiles, and those of blighted corn. These animalcula become quite dry and apparently dead by being deprived of moisture, and this state may be protracted or abridged at pleasure, by moistening the sand in which they are placed. Moisture is to them what heat and food are to hybernating animals; for, when deprived of water, which keeps up the relation between their bodies and the external world, their functions are suspended, and may be revived by the application of moisture, even after they have been kept in a state of suspension twenty-seven years,—as the experiments of Mr. Needham and Spallanzani show *.

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* Spallanzani's Tracts on the Nature of Animals and Vegetables, p. 251.

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Some bats become torpid in summer, but the number is very small which forms so remarkable an exception to the general law. Spallanzani, however, has seen them in that state during summer; and as these animals appear to possess some voluntary power over their respiration, it is not unreasonable to suppose that this state of torpidity is in consequence of some instinctive propensity to preserve life. And this I think furnishes a strong argument against the opinions of M. Du Pont de Nemours.

The third and fourth objections of Mr. Gough are exemplified by an account of some singular anomalies in the history of man himself, and by some interesting details respecting the manners and habits of dormice, in which he clearly proves that the torpidity may be obviated

viated by generous diet and warmth: but I cannot agree with this excellent experimentalist in considering "the torpidity of these animals in a wild state to be nothing but a custom imposed by necessity on a constitution which nature has intended to retain life during the cold season of winter, with but little food and an imperfect degree of respiration, as well as a languid or perhaps a partial action of the sanguiferous system*."—And I am disposed to draw an opposite conclusion to Mr. Gough, from the very arguments he has used in support of the converse of the proposition concerning the natural habit of hybernating animals.

He has adduced several instances of animals being compelled by strong cir-

* Letter ii. in Nicholson's Journal, vol. xix. p. 166.

cumstances

cumstances to relinquish their characteristic manners, in order to act a part contrary to the uniform habits of their species. Linnæus has preserved the memory of a tame fieldfare (*Turdus pilaris*,) belonging to a vintner at Stockholm, which learned to drink wine, and became bald in consequence of this strange beverage. Mr. Gough mentions also that he knew a mastiff, which was equally fond of ale, and never failed to get drunk when an opportunity offered. The hyæna lives on the roots of fritillary in the unfrequented parts of Africa; but in the vicinities of populous cities it changes into a disgusting glutton, feeding on filth and carrion.—The hog, in its wild state, is a cleanly animal; and seems to delight in wallowing in mire and in nasty ways, because it suffers so much irritation and uneasiness on its skin

skin in a domestic state; partly, perhaps, from want of a sufficient supply of moisture, and partly from the hot and stimulating kind of food. The pied fly-catcher (*Muscicapa atricapilla*) lives on soft seeds and insects in this country; but its food is very different in Norway, especially during winter, when it repairs to the habitations of men, and subsists on flesh dried in the smoke. Spallanzani converted a pigeon, which is granivorous, into a carnivorous bird, by inducing it in the first place to eat fresh meat, and afterwards to give a preference to putrid animal substances. Mr. John Hunter gradually brought a hawk, and Spallanzani accustomed an eagle, to live upon bread, though both these birds naturally live upon flesh. Cattle in some countries are fed with salted fish in the winter season; many animals change their food in the

the course of their lives: and a total alteration in the diet of any animal may be effected without danger, provided the alteration be gradual.

Some nations live entirely on vegetable food, and others never taste any thing but animal substances; vegetable food is more generally taken in warm climates; animal food, in cold countries; and the inhabitants of temperate climates eat a mixture of both. Some tribes of savages live wholly on flesh, and eat it without cooking: the Greenlanders and the inhabitants of the north are fed on fish, and principally on parts of the whale; and Crantz assures us that the head and shoulders of a sea-dog or shark are hidden by these people, under the grass in summer, and under the snow in winter; so that half-frozen and half-putrid flesh is devoured with an eager-

ness

ness equal to that of an European eating the best ham.

The crews of ships in long voyages, and in shipwrecks, have been frequently reduced to the greatest distress for want of food, and serve to show how wonderfully the human frame is capable of accommodating itself to circumstances.—Many other instances might be brought forward, but these are abundantly satisfactory with regard to the efficacy of the principle of accommodation which regulates the animal œconomy.

Still the question recurs, Is torpidity merely an accidental habit, or is it a natural propensity?

Particular experiments will not enable us to decide this question; they will not lead to a legitimate conclusion: we must take the history of every animal from its

its manners and habits in the situation in which it is placed by nature, not from its appearance in any forced or unnatural condition. Peter the Wild Boy, and the Savage of Aveyron, caught in the woods, where they had always lived apart from their species, are singular and anomalous examples ; they are not specimens of the natural character of man, and ought not to be considered as such. If a solitary bee should by chance be found in a wood humming and buzzing about, ought it to be concluded that this bee is in a state of nature, and that those who work together in a hive are an artificial and degenerate race?

Every animal is endowed with certain instinctive propensities, to which it is irresistibly subject and necessarily obedient in its natural state. If I am asked, What is this instinct? I answer, By the term

term *instinct*, I understand "a predisposition for certain actions when certain sensations exist*;" it is the arrangement of certain organs, which are developed and called into action by peculiar circumstances. This instinct cannot be displayed so completely when animals are kept in a forced situation: if dormice are supplied with food, their torpidity is imperfect; they sleep during the day, but they awake every night to eat.

Observations made on dormice from the beginning to the end of winter show that their confinement, and their being subject to frequent interruption, prevent them from becoming torpid, although exposed to a degree of cold below the freezing

* Browne's Observations on Darwin's Zoonomia.

point. Spallanzani observed fourteen dormice, which he kept in a cage, become torpid on the 12th of November, and for several days following, at a temperature of 43°, and even when the thermometer stood higher: but what is singular, these animals were so torpid in the day-time as to be rolled up in the shape of a ball, to have their eyes closed, to be cold to the touch; and yet they awoke at night and ate, and fell asleep again in the morning. These observations were made on dormice kept in a cage upon his window, exposed to a temperature 35°, 38°, 40°; and he was particularly struck with their becoming completely torpid for several successive days in the month of March on the recurrence of the cold weather, whilst their torpor had alternated with waking during the winter: he conjectures the sensation of hunger, which these animals

animals might experience in the night, to have been the cause of this remarkable effect *. He shows also in the same memoir, that dormice kept in a situation more resembling their wild state became torpid in the month of November, and remained till the middle of March without eating the food which was supplied for them.

When I was in Switzerland I procured two young marmots in September 1805, and kept them with the view of determining the question whether their torpidity could be prevented by an abundant supply of food and moderate heat. I carried them with me to Vienna, and

* Mémoire sur les Loirs. Vide Rapports de l'Air, &c., tom. ii.

kept them the whole of the winter 1805-6: the months of October and November were very mild; my marmots ate, every day, turnips, cabbages, and brown bread, and were very active and lively;—they were kept in a box filled with hay in a cellar, and afterwards in a room without a fire, and did not show any symptoms of growing torpid.

December 18th the weather was cold, and the wind very sharp; Fahrenheit's thermometer stood at 18° and 20°: two hedgehogs died which were kept in the same room with the marmots, and a hamster died also in a room where a fire was constantly kept, though these animals had plenty of hay and food. The marmots became more torpid than I ever saw them before, yet they continued to come out of their nest and endeavoured to

to escape; the food given them in the evening was always consumed by the next morning. In January the weather was unusually mild and warm; my marmots ate voraciously, and were jumping about in the morning: but at four o'clock in the afternoon I examined them several times, and found them not completely rolled up, half torpid, and quite cold to the to ch: they continued in this state of semi-torpor for several weeks longer, never becoming so torpid as to live many days without eating, and never so active as to resist the benumbing influence of the cold weather.

I regret not being able to give any further account of these animals the following winter, as the interrupted correspondence occasioned by the war has prevented me from hearing often from my friend Dr. Schreibers, the professor of

of natural history, to whose care I committed them when I left Vienna; since which time they have been lodged in the imperial menagerie at Schonbrunn.

If any inference can be drawn from these remarks, it is in favour of my opinion that torpidity is a natural instinctive propensity. Did not the marmots become almost torpid, although confined in a box? What habit could they have acquired? Whose instruction could they hear? or whose example did they follow? They were both young; they were caught early in the summer; they were supplied with plenty of food; and they had both grown extremely fat: and yet they were both affected by the variations of temperature in a most astonishing manner. Hence I am induced to think differently from Mr. Gough upon this subject,

subject, and with all due deference to his good judgement, I am apt to suspect that he has been led away by the result of his own experiments, and by a similar one related by the celebrated Pallas, and that he has attributed to the effects of regimen what is the result of many other circumstances cooperating together.

The professor of natural history at Vienna has kept tame marmots: he informed me that they might be kept alive and free from absolute torpidity throughout the winter, in a warm room, by a plentiful supply of food, but that they were frozen to death if allowed to remain in a very cold situation: when brought into a warm temperature, during their torpid state, they were roused into action; but, if this experiment was often repeated, the animals died violently agitated, and

hæmorrhage

hæmorrhage took place from the mouth and nostrils.

Those marmots which are kept in houses, says Girtanner*, never become torpid; but towards the approach of winter they feel the influence of instinct, collect themselves into groups, and gather hay to make a nest. The observations which I have been able to make prove the reverse, and I am happy to have them confirmed by the authority of count Matsuschka: his tame marmot became torpid in winter for more than one season, it retired and rolled itself up as it does in the wild state: in the middle of September 1783, it carried hay and straw and hid itself behind a stove in the servants' room: it did not appear

* Lichtenberg's und Voigt's Magazin für das Neueste der Physik, b. iv. s. 17.

after

after the 6th of October;—and on the 5th of April 1784 it came out of its retreat, after remaining six months without eating or drinking *.

The nearer hybernating animals are allowed to approach their natural mode of life in a domesticated state, the more they follow their natural habits, as we see that confinement prevents them from becoming torpid either with or without food, and a liberty of indulging their own feelings shows how congenial torpidity is with their nature. The marmot, therefore, if any animal be naturally torpid, is so in an eminent degree: it can, as well as the dormouse and the hedgehog, live without sleeping through

* Naturgeschichte der Europaïschen Thiere, von J. A. Goeze, b. ii. p. 224.

the

the whole winter; but its tendency to torpidity is by no means artificial, nor could we bestow upon other animals the disposition to become torpid at the approach of winter, any more than we could give to ourselves a new organ of perception.

Hybernating animals are always found where the low temperature and the want of proper food render torpidity inevitable: marmots are found on the tops of mountains, and the tribe of Glires abound most in Russia. Torpidity then may be said to be *natural* to them, since they are subject to it in situations where they are placed by Nature; a difference is observed in their organization, evidently designed to answer some important purpose; and existence in a condition for which a peculiar provision is made may, therefore,

therefore, be justly considered as natural.

That animals can live without becoming torpid, is no argument against what I have endeavoured to prove. This also is a necessary consequence of instinct; and is to be explained upon the above-mentioned principle, that "certain actions take place when certain sensations exist;" and when these do not exist, the actions do not ensue, because the propensities are only excited where the disadvantages exist against which the instinct provides. Diminished temperature and the want of food are the first steps in the series of phænomena which constitute torpidity; and I have endeavoured, in a former part of this essay, to point out the successive changes which intervene between the abstraction of external heat and nourishment,

ment, and the complete suspension of all the animal functions.

The conditional exemption of certain hybernating animals, and some remarkable facts in the history of mankind, have led some persons from analogy to attribute the same accommodating faculty of becoming torpid to all other animals. Mr. Gough is inclined to favour this supposition, and has adduced some singular facts in support of it. Sheep in Iceland live under the snow; and frequent instances occur in Cumberland and Westmoreland, and in the Highlands of Scotland, of sheep living four or five weeks under drifts of snow, where they can procure little or no food, and must, it is supposed, become torpid. Dr. Plott, in his History of Staffordshire, relates several wonderful cases of persons continuing

tinuing asleep for seven or fourteen days, apparently from the influence of fear and anxiety, and other causes which tend to weaken the action of the vital powers; but they do not strike me as applicable to the point in question.

One of the most striking instances with which I am acquainted, occurred within my own recollection, and the truth of it there is not the least reason to suspect. Elizabeth Woodcock of Impington, near Cambridge, in returning from market on Saturday evening, Feb. 2d 1799, was lost in a storm of snow which drifted over her about six feet deep, under which she lay buried, without food, until Sunday noon the 10th of February, when she was found alive and sensible, though she died some weeks after, from mortification of her legs. It did not appear that she had slept a great deal,

deal, because in all the accounts it is expressly mentioned that she remained sensible during the whole time.

I have read accounts of the Swiss peasants being frequently buried in their huts by an avalange, and, after remaining under the snow for a considerable time, having recovered by the use of proper means. But I can discover no satisfactory evidence of such instances having really happened.—From one narrative published*, it appears that the poor wretches were in constant dread of being starved; but I never could learn from any body in Switzerland that a similar circumstance ever occurred; though I have frequently been told of men being lost in snow on

* "Narrative of three Women saved who were buried 37 days under the Snow in a Stable at Bergemoletto, in Italy," by F. Soumis. 12mo. 1739.

the

the mountains, and that when found, several months after they had disappeared, their bodies did not show the least signs of putridity, the cold having prevented any sensible decomposition.

Though there are some singular histories in medical records which may appear to favour the supposition that man may become torpid under certain circumstances, yet we have the most positive evidence that no such state was produced by causes which in other animals strongly predispose to it.—Dr. Currie, in a very interesting account of the remarkable effects of a shipwreck on some mariners, mentions that these unfortunate men remained twenty-three hours on the wreck, and of fourteen, the original number, eleven in the end recovered:—they were exposed to the air and to the sea water, the temperature of both which,

as

as nearly as could be guessed, was from 33° to 35°; and though exposed to such severe cold for so many hours, without any sort of food, or any liquor to drink, none of them were drowsy, nor did sleep precede death in any of those men who perished *.

When we reflect how wide the difference is between man and other animals, especially in what regards their adaptation to climate, it will readily be admitted that the arguments from analogy are fallacious; and in conjecturing that all animals, even the human species, might be rendered torpid with safety, there is danger of falling into that error which supposes events that do not exist.

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* Phil. Trans. for 1792.—Medical Reports on the Effects of Water, vol. i. chap. xv.

With

With plants the analogy appears more convincing, for there is great resemblance between hybernating animals and plants in the winter; and the fact of torpidity establishes a new relation between the higher classes of animals and insects and vegetables. The greater part of plants lose their verdure at the approach of winter; they have but little sap, and that is motionless; they cease to take in nutriment, to grow, or to multiply their species; hence complete inaction is produced; and they revive again in spring, like insects and torpid animals, after having apparently been reduced to a lifeless mass.

Mr. Gough has related some instances of suspended animation in vegetables, particularly in the *Lemna minor*, or common duck's-meat, and the *Festuca vivipara*; and his experiments corroborate

the analogy between vegetables and animals, since they show that a certain description of organized beings, belonging to both kingdoms, are enabled by this provision to accommodate themselves to the vicissitudes of variable situations, and to preserve not only the life of the individual, but perhaps the existence of the species, by submitting to a temporary death, or rather to a complete suspension of life. The seeds of land plants which germinate on the surface of the ground, being exposed to the inconveniencies of the weather, in common with aquatic plants growing in shallow ponds, are provided with the same principle of accommodation to insure their safety*.

Let us now consider the extraordi-

* Nicholson's Journal, vol. iv. p. 511, First Series.

nary

nary degrees of cold, ascertained by thermometrical observations, which the human body is capable of sustaining, and does indeed undergo, without any peculiar difference either in constitution or in the mode of life. The greatest natural cold accurately known is that observed by Gmelin in 1735, at Jeniseisk *, in 58° north lat., 110° long. This cold began in January, and was so severe that the mercury in the thermometer fell down to 120° below zero, that is, below the degree which Fahrenheit's scale marks when plunged into a mixture of muriat of ammonia and ice. Pallas, in his travels through Siberia, remarked, on the 7th of December 1772 †, at Krasnajorsk, 56° lat., 110° long., that the thermo-

* Flora Sibirica, Preface.

† Travels in Russia, vol. iii.

meter fell to 80° below 0°: yet this was not the greatest degree of cold; for, when the mercury descended lower than the scale was marked, it sank into the bulb and was congealed. A mass of quicksilver exposed to the air was frozen, and became partly malleable.

The cold experienced by some of our countrymen at Hudson's Bay was not accurately measured, but it must have been nearly as great. Captain Middleton assures us, that the lakes which were not above ten or twelve feet deep were frozen to the bottom, and that even in heated rooms wine and spirits could not be kept in a fluid state. In the long days of winter the English there hung up in their rooms twenty-four pound balls heated red hot; and although they kept an immense fire, yet soon after it was out the walls of the room and the beds were

covered

covered with layers of ice three inches thick*. Great as this degree of cold is, yet man is capable of enduring it, provided he keeps using exercise: he is able to resist, by exerting his powers, what animals are compelled to submit to, by resigning themselves up to complete inactivity.

The savage inhabitants of Canada, whose dwellings extend almost up to Hudson's Bay, and the Esquimaux, go hunting when the cold is excessive. And we are not to suppose that the natives of the coldest parts of Siberia never stir out of their huts, except in mild weather.

Many examples are on record of Europeans, who may be supposed less hardy, braving extreme degrees of cold. Some

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* Philosophical Transactions abridged, vol. viii. p. 470.

Hollanders

Hollanders in 1597, under the command of Hemskerk, were obliged to pass a winter at Nova Zembla under 76° north lat. Their wine was frozen, although their hut was covered in and heated. Some of them perished; but those who took exercise, and were otherwise in good health, were able to withstand the cold which even the white bear, a native of these regions, could not support. The journal of these Dutchmen expressly mentions, that as soon as the sun quits the horizon, which it does in these regions for several months, the cold becomes so severe that the bears are seen no more, and only the white fox (*Canis lagopus*) is able to live there with man *.

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* Zoologie Géographique, par E. A. Zimmerman.

Animals

Animals are furnished with thick fur, and are provided against the effects of cold, which man supports without any particular provision, and without even thick clothing. The Greenlanders go about with very light clothing, and with their heads and necks uncovered; and the peasants in Norway work during winter with their bosoms bare; and when heated by exercise they roll themselves in the snow without any bad consequences.

If mankind were not exempt from that law of Nature which forces such numerous tribes of the inferior animals to become torpid, we should have found it exemplified in some of the situations in which men have been placed either by accident or by the common course of things. No allusion is made to so singular an event in the physical history

of

of our species; and therefore we may conclude that it has never occurred, and is inconsistent with the established laws of the human frame.

It may be objected to this conclusion, that mankind are liable to suspended animation from drowning, or breathing noxious gases, and are sometimes restored to life after being apparently dead. The facts, however, connected with submersion are not irreconcileable with what has been already said concerning torpidity. There is an essential difference between the two cases. I consider drowning or suffocation as a case of syncope, produced by certain causes acting upon the centre of the system and influencing the remote parts, whereas torpidity from cold first affects the sentient extremities of the nerves, and is propagated gradually to the centre. The

The change which takes place in the blood and in the air in the lungs, is necessary for the support of the muscular action of the heart; and when that action has ceased, provided the cessation has not been for any long time, it is capable of being restored by inflating the lungs with atmospherical air or oxygen gas.

Death takes place in drowning from the exhaustion of the irritability of the heart, probably in consequence of some change taking place in the muscular and nervous fibres of that organ, from the sudden loss of that stimulating power which the blood acquires in the lungs. In these instances, death comes on without the temperature being much reduced. Diminished temperature, therefore, is not the primary cause of suspended animation in submersion, or breathing carbonic

carbonic acid gas: if that were true of drowning, as it is of torpidity, animals could not be drowned in a temperature so high as or higher than their own.—The great influence of atmospherical air on the action of the heart, shows the importance of inflating the lungs as the first step towards the recovery of drowned persons, whilst the loss of irritability must be attempted to be restored by communicating heat and tension to the faint and exhausted system.

In all organized beings, the final cause of respiration is the same: but the organs by which this function is carried on are exceedingly varied; and it is curious to observe, that the more perfect respiration is, the more concealed are the organs which perform it, consequently less likely to be influenced by changes in the temperature of the atmosphere. Birds, whose

whose respiration is so perfect, and whose temperature is so high, that I have ventured to remark that they never become torpid from cold, have the air conducted not only into their lungs but into the cavities of some of their bones. Their respiratory organs are very different from those of oviparous quadrupeds, which constitute the most numerous class among hybernating animals.

The leaves are the organs of respiration in vegetables; and as these are employed only during a part of the year, there is no difficulty in believing that trees and plants become torpid in winter. But the constitution of the human body is so widely different, the powers of the human mind are so adapted to supply food, and external warmth, and whatever can counteract the benumbing effects of cold, that it seems to me more philosophical

phical to look upon the exemption of mankind from torpidity as another characteristic mark of their superior nature. The use of clothing, the discovery of the use of fire, and the regular vicissitudes of sleeping and waking which are necessary to support and recruit the continual waste of the system, all militate against the possibility of animation being suspended for any length of time from the operation of cold. To which may be added the total want of authentic histories of such occurrences in countries where external circumstances are most favourable for them.

SECTION

SECTION IV.

GENERAL REMARKS ON TORPIDITY, ON SLEEP, AND ON THE APPLICATION OF COLD IN DISEASES.

In attempting to explain any fact in natural history, we must first determine what appearances necessarily constitute its nature, and then choose, among the general laws which regulate the œconomy of animals, a sufficient ground for the production of the phænomena. The first part of this task being already performed, I now proceed to enumerate the circumstances which form the remaining part of my subject, and I shall conclude with

with some general reflections which have been suggested.

The remote causes of torpidity in animals induce directly or indirectly a periodical debility in the vascular system, which debility is connected with an alteration in the crasis of the solids and fluids, and in the action of the nervous system. That debility is proved by the weakness of the pulse, by the suspension of respiration, by the diminution of the temperature, and by the accumulation of the blood in the internal parts: the alteration in the crasis of the solids and fluids must be a probable consequence of the changes observed in the secretions, particularly in the lungs, in the stomach, and in the muscles. The nervous system, whose energies depend so much

much upon the mechanical and chemical effects of the circulation, partakes of the affection of the vascular system, and is perhaps one of the most immediate means of diffusing the influence of that affection over the rest of the body.

Cold and the want of food are the principal remote causes of torpidity: it is only necessary to attend to the progress of the phænomena to be assured of this, and negative arguments can never invalidate the positive evidence of accurate observers. It may be said that these causes merely act upon a predisposition, or excite it to break out when its germs already exist: but, in truth, all predisposing and exciting causes pass into each other; they are one and the same, when considered relatively to the state of the animal itself; they all change the powers

of

of the system, and that new condition of the system is the proximate cause of torpidity.

Animals become torpid under precisely similar circumstances in every quarter of the globe ; and I am more inclined to attribute these alleged effects to cold and want of food, because they may be kept alert during winter by a constant supply of caloric and nourishment.

The late Dr. Currie, after having successfully devoted his attention to experimental inquiries into the relations of animal temperature in health and disease, has extended the influence of this one process over all the phænomena of life, and even grounded his distinction of vitality upon it. "If a definition of life were required," says he, "it might be most clearly established on that capacity by which

which the animal preserves its proper heat under the various degrees of temperature of the medium in which it lives *."—The phænomena of torpidity, however, prove this sweeping conclusion to be as unfounded as many of those which that distinguished writer so justly condemned; although it may be true as far as the human body is concerned, which Dr. Currie has exclusively examined.

From the circumstances attending the torpidity of warm-blooded animals being precisely similar to those of the other classes, a very powerful and incontrovertible argument may be deduced against the hypothesis that life is a forced state, and depends altogether on the continued exhibition of stimulants. The same facts also prove the weakness and insufficiency

* Medical Reports, vol. i. p. 264.

of the theories of Dr. Brown and Dr. Darwin, in that position common to them both, that the sensorial power, or excitability, is a substance which accumulates and diminishes in the inverse ratio of the stimulation. For the series of changes in torpid animals are inexplicable upon their hypotheses; instead of being periodical the torpor would be permanent, according to their theories. They have overlooked the influence of cold upon the sensations which Dr. Currie has the great merit of pointing out, and they have not attended to the manner in which the system recovers its excitability.

The theory of the production of animal heat by respiration is far from being perfect: indeed, the chemical investigation of any one animal function cannot at present be followed out to any great length

length separately from the rest. An organized body is a whole, in which phænomena arise from and mutually depend upon each other, with due relation to external physical circumstances. Some important facts, however, have been discovered; and I think that I am authorized in drawing the following conclusions from the present inquiry:—

First, That the temperature of animals is essentially connected with the function of respiration.

Second, That the temperature may be varied by corresponding variations in the respiration, without injury to life; but this range of variation is less in the more perfect animals than in the *Amphibia* or cold-blooded.

Third, That it is most uniform in man, and in animals which consume most oxygen, though uniformity of temperature

is not to be considered as the most essential characteristic of animal life.

Lastly, That torpidity is natural to some animals, and is the means furnished by nature for preserving life under circumstances of difficulty and danger.

It only remains now to conclude with some reflections suggested by the facts detailed in the foregoing pages.

In tracing back the phænomena of hybernation, we cannot help being struck with the great influence of three principal functions, *respiration*, *perspiration*, and *digestion*; besides the action of the nervous system, which it is impossible exactly to estimate or describe.

Nothing can be more admirable than the result of forces continually varying and continually balancing each other, which are observed every moment in the animal

animal œconomy, but particularly in animals under the influence of cold. Respiration, by producing in the lungs, and probably in other parts of the system, a slow combustion of the hydrogen and carbon contained in the blood, occasions a disengagement of caloric absolutely necessary for the existence of animal life: perspiration facilitates the disengagement of some portion of carbonic acid, and perhaps some other noxious matter, by giving out perspirable matter to the surrounding air, and prevents at the same time the accumulation of any excess of heat: digestion furnishes the blood with water, hydrogen, and carbon, and not only restores to the animal machine what it loses by perspiration and respiration, but afterwards rejects what is hurtful or superfluous.

This is what takes place in the ordinary

nary state of the animal œconomy ; but when the external circumstances are varied, the resources are equally multiplied, and the equilibrium is still preserved. When the two faculties of sensation and voluntary motion are suspended, they influence all the collateral functions. If an animal be reduced to a state of inaction and repose, the respiration becomes slow, and the circulation likewise ; it consumes less air, exhales less from the lungs and skin, and consequently has less need of nourishment. If it be roused to great exertion, the respiration is accelerated, the consumption of air is greater, the exhalations are more considerable, and consequently a larger supply of food is necessary to repair what is expended. In this case, if the equilibrium cannot be kept up, disease and death is the consequence. Man in this respect is

far

far superior to all other animals: he can live in all temperatures, and in all climates: his functions are more capable of resistance to external circumstances, and his system triumphs where others yield.

If he be exposed to intense cold, the contact of the air with the lungs becomes more considerable from its greater density; more air is decomposed, and consequently more caloric is disengaged, which supplies the loss by the external temperature, whilst the perspiration diminishes; and as the evaporation becomes less, the internal warmth is better preserved. The contrary effects take place, if he go into a hot climate. The air being less dense, its contact with the blood in the lungs is less considerable, a smaller quantity of air is decomposed, less caloric is disengaged, a more abundant

dant perspiration is established, a greater quantity of caloric is carried off, and in this way an almost uniform degree of heat is observed *.

There is some analogy between torpidity and sleep: both of these situations, into which the animal system is thrown, are not usually termed diseases, when in moderate degrees; yet they abound with many curious phænomena very opposite to the common acceptation of life and health. The body during sleep loses partially or wholly its excitability, or the power of being acted upon by the different states of mind which its actions were accustomed to succeed; but the susceptibilities of the mind itself con-

* Johnson's Animal Chemistry, vol. iii.

tinue

tinue nearly the same as in the awakened state. The vital functions continue during sleep, but they are exercised with less force:—the pulse and respiration become slower, the temperature of the body is diminished, the peristaltic motion of the intestines retarded, and all the secretions and excretions decreased.

Sanctorius and Dr. Darwin have contradicted this statement of facts. They assert that the pulse is increased in frequency, that the evolution of caloric is greater, and the assimilation of aliment more rapid and complete: but these assertions are unsupported by proofs.

It is well known that the frequency of the pulse is diminished during sleep, and becomes softer; which is observed in fevers, and in diseases accompanied with local inflammation. The evolution of caloric is less, because the thermome-

ter indicates less heat upon the surface after sleeping several hours in fevers, because more covering is required to keep us from feeling cold than when awake; and because a person complains of cold and is chilly when he awakes, if he goes to sleep in a chair, even before a fire.

It is impossible to state the precise quantity of secreted fluids during sleep, because a part may be reabsorbed into the system: with respect to perspiration, that appears from the experiments of Bryan, Robinson, and Keil, to be diminished. In salivation from mercury, the discharge is less during the night: in diarrhœa also, and in catarrh, the secretions are much less in the night than during the day, and the quantity of urine is less in any given time passed in sleep. The secretion of adipose matter

ter has been said to be one exception to the general rule ; for it is well known that animals which sleep much, grow fat ; and this circumstance is taken advantage of by those who fatten cattle and fowls for market. This seems to have given rise to the vulgar error, that animals grow fatter during their winter torpor, whilst it is forgotten that the requisite supply of nourishment is suspended. The fact, however, holds good with regard to the effect of much sleep upon man. Boerhaave relates the history of a physician who took it into his head that sleep was the natural state of man ; and in compliance with his favourite theory he slept eighteen out of the twenty-four hours, till he became very corpulent, and died suddenly of apoplexy.

The remote causes of sleep may be all arranged under three heads :—

First,

First, Those which diminish the powers of the system for action.

Second, Those which take from arterial blood its power of supplying the excitability of the system.

Third, Those which have been called by Dr. John Brown directly debilitating, which consist in the abstraction of those stimuli absolutely necessary for existence.

Fatigue of body and mind,—diminished quantity of oxygen in the air received into the lungs,—removal of impressions from external stimuli, as light and heat,—removing uneasy sensations, are the principal remote causes of sleep.

Opium and other narcotics induce sleep in a way somewhat analogous to mental and corporeal exertion ; but in what this diminished aptitude for labour consists, is not known, though the fact

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is observed daily. The mode in which cold acts in producing sleep is difficult to be explained according to the common theories; since the sensation of cold in the feet, or in the fingers, is one of the most certain means of preventing sleep, while excessive degrees of cold irresistibly dispose to it. All the phænomena of sleep and torpidity show that both are affections of the nervous system; but what is the particular state of that system, and in what the difference between them consists, cannot be satisfactorily explained. We are ignorant how the functions of the nerves are performed, and therefore we cannot be expected to explain how they are interrupted.

It was common among physiologists to refer the operation of the senses to a particular secretion in the brain and nerves,

nerves, called *animal spirits*, or *nervous fluid*. Sleep was attributed to the exhaustion of this fluid, and the awakened state to its accumulation. But the existence of this fluid is quite hypothetical; the tubular structure of the nerves is not ascertained; and no fluid was ever seen, except by Fontana; and what he describes is a gelatinous liquor very different from what would be supposed fit for the purpose of conveying impressions. No place has been found in the brain for its accumulation, and no traces of it can be detected in that organ.

After refuting this theory, Haller substituted the following: he compared sleep to a state of apoplexy, produced by accumulation and pressure of blood in the brain. But natural sleep differs very much from this kind of sopor; the body is not recruited or refreshed by it,

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as we find all sorts of compression upon the brain tend to exhaust the muscular solid, and the symptoms of apoplectic sopor are manifestly different from those of sleep. A tendency to sleep is produced by profuse hæmorrhage, especially in the erect posture, when no accumulation in the head can be suspected; and we are told that the Romans, who voluntarily opened their veins in the warm bath to avoid the fury of their tyrannical emperors, fell into a state of slumber before death.

These two theories being considered insufficient to account for the phænomena, Dr. Cullen suggested another which has given birth to great discussion. He supposed that sleep was owing to a change in the nervous system, by which it became torpid and less readily brought into action, and to this state he gave

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the name of *collapse*. Under the term collapse all the animal powers are included, because he supposed the muscles to consist of nervous fibres; and the term itself corresponds exactly with the *debility* of Brown, and the exhaustion of the *sensorial power* of Darwin. Our waking state Cullen called that of *excitement*, which he distinguished into two kinds, as they relate to the mobility or vigour of the system, and in the same way he distinguished in collapse the states of torpor and weakness. He afterwards showed, by a copious induction from facts, that these states of excitement and collapse may exist in any part of the body, and that they might be more or less partial and unequal; and he concluded that sleep consisted in a collapse of the nervous system in general, and of the brain in particular. This

opinion

opinion is supported by reasoning extremely hypothetical and vague, and can only be considered an unsuccessful attempt to generalize the phænomena of sleep. In his examination of the remote causes there is one valuable remark, viz. that all the causes of violent excitement in the end produce collapse.

The acuteness and sagacity of John Brown soon led him to detect an error in his master's theory, which served as the foundation of his own. He remarked the inconsistency of attributing the same effects to opposite causes, as in saying that sleep arose from the absence of impressions and the gratification of most vehement desires, from exposure to severe cold, and from warmth, from the abstraction of blood, and the taking food into the stomach, from great excitement, and from none at all. Having

detected this fallacy in Cullen's explanation, he proceeded to deliver his own. He observes that 'life is a forced state,' an opinion which has gained a great deal of credit for him and his doctrine, but which in truth first originated with Dr. Cullen. The remote causes he arranged under two heads, either the direct or indirect debilitating powers; the ultimate effect of which in every instance is said to be debility or collapse.

The author of Zoonomia has arrived at the same conclusion, though he has followed a different course.

The Brunonians have searched after resemblances of excitement more than its differences; hence their works are disfigured with false generalizations, and their practice has vibrated between negligence and rashness; hence their curative indications are marked by total neglect

lect of the connections and dependences of the different functions and of the organic derangements which take place in diseases.

As to the disputes about the operation of cold, these have been carried on by logical deception, and by the false interpretation of two words; since all that can be understood by the appropriated terms *stimulant* and *sedative*, amounts to this, that one standard of temperature is not the same for exciting the energies of all organized beings, because it varies with the capacities of different orders, and even of the same orders under different circumstances.

The effects of cold, as a remedy in diseases, might be considered in two separate parts, the first of an historical nature, the second as a practical inquiry. Upon each of these heads many valuable

remarks may be found in several medical and philosophical works published within these few years, particularly in *Rigby's Essay on Animal Heat*, 1785; *Currie's Medical Reports*, 1804; *and Stock's Medical Collections on the Effects of Cold, as a Remedy in certain Diseases*, 1805.

Cold water and cool air applied to the surface of the body prove highly grateful and salutary, and often operate like a charm in arresting the progress of the most formidable febrile diseases. The most striking effect of the affusion of cold water, or of washing the whole body, is its inducing sleep; which is the most unequivocal sign of its doing good, as sleep is accompanied by the diminution of the temperature, a reduction of the frequency of the pulse, removal of the uneasy sensation of heat, and frequently by

by the complete suspension of the whole train of morbid actions.

Although the symptoms of fever do not consist merely of actions which arise from a preternatural accumulation of heat, yet the temperature of the body is certainly an object of the first importance. When the skin is very hot, the pulse is very quick; the increased temperature is always associated with increased vascular action; and this morbid accumulation of heat becomes a source of irritation to the nervous system, and becomes likewise a cause of its own continuance, unless removed by artificial means. If allowed to continue for many hours, we observe that this febrile heat diffuses itself over every part of the body, deranges the functions, weakens the connection between solids and fluids, decomposes the animal matter, and at length

length destroys the organization. The application of cold water and cool air proves grateful and salutary, not only by removing the disagreeable sensation of heat, but by some direct and positive impression upon the nerves. That impression is called a *shock* ; and we find that a shock given to the sensibility of the system frequently removes a febrile disease. At the commencement of typhus and scarlet fever, the curative effects of the cold affusion are particularly observable. The most important circumstances to be attended to in the application of this powerful remedy, are comprised by Dr. Currie in three general rules which cannot be too well known, nor too often repeated.

I. It may be used at any time when there is no sense of chilliness present:

II. When

II. When the heat of the surface is steadily above what is natural: and,

III. When there is no general or profuse sensible perspiration.

Unlike most other useful propositions in physic, this remedy has never been attacked, the experience in its favour is complete and incontrovertible; yet it is not employed so generally as it deserves, owing to unfounded apprehensions, and to prejudices which time alone can remove. I am disposed to think that some of these prejudices may be overcome by extending our views to the operation of such a powerful agent as cold, upon other bodies besides our own; and with this view, perhaps, some remarks contained in the foregoing pages may not be entirely useless. By looking into physical causes, our minds are opened and enlarged; and, whether we gain the information

information we wish for, or whether we lose sight of it, some advantage is always derived from the pursuit. "Est animorum ingeniorumque nostrorum naturale quoddam quasi pabulum consideratio contemplatioque naturæ," says Cicero. If the lights derived from such interesting speculations can be directed upon the different branches of natural science, whilst we investigate the causes and trace the series of actions in organized bodies, we may not only communicate to physiology solid information, but we may reflect back upon medicine some knowledge of the vital functions, without which the greatest proficiency in that science will have something defective.

FINIS.

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